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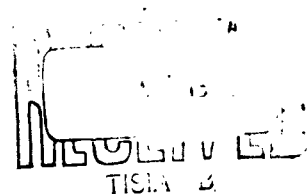
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**MILITARY
COMPUTER
MAINTENANCE**
(PROJECT HEADSTART FINAL REPORT)

by

H.W. ADAMS

THE
MITR
CORPORATION

SR-66

MILITARY COMPUTER MAINTENANCE
(PROJECT HEADSTART FINAL REPORT)

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H. W. Adams

August 1962



Bedford, Massachusetts

**This Special Report has been approved
for public dissemination.**

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ABSTRACT

Project Headstart is a study of the feasibility of military computer maintenance based on the maintenance of a pilot site, the Washington Air Defense Sector of SAGE. A comparison was made of the IBM experience and of the Air Defense Command experience in maintaining this site. The comparison indicated that military maintenance of SAGE computers was as effective as contractor maintenance.

ACKNOWLEDGEMENTS

The work reported in the following pages was done by many persons and rested on the cooperation of many more. The initial idea for the study came from a similar study, done by Alaskan Air Command, under the encouragement of United States Air Force Headquarters (HQ USAF), specifically the Communications and Electronics Division of the Directorate of Maintenance Engineering and the Contract Services Branch of the Directorate of Manpower and Organization. Throughout the study, we at The MITRE Corporation experienced complete cooperation from all levels of the Air Defense Command, and of the Federal Systems Division of the International Business Machines Corporation.

Special mention must be made of the efforts of Capt. William T. Misencik of Washington Air Defense Sector Headquarters, Mr. J. Montgomery Joel and Dr. Frank P. Gatling of MITRE, without whose work our study would have lacked an adequately valid base of reliability measurement data; and of the thorough and rigorous manner in which these data were interpreted by Mr. William S. Rouse of MITRE.

We cannot praise too highly the assistance and insight given us by Maj. Stanton G. Daries of Air Defense Command Headquarters, who is largely responsible for organizing the program which made military computer maintenance of the SAGE computers a reality; and the continued support given us by Mr. Richard L. Gilbert and Lt. Col. Dean B. Mohr of HQ USAF to "call the shots as we saw them."

Finally, much of the success this study has had is a direct result of the continued guidance I received from Dr. James W. Degan; his balanced perspective kept me from making many errors of judgment.

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THE "CONTRACTOR PROBLEM"

After the Korean War, the Air Force found itself with an increasingly severe manpower problem: how to get enough technicians to maintain its growing inventory of electronic equipment. Because of manpower restrictions, the Air Force was not able to fill this increasing requirement for skilled manpower from its own ranks. Therefore, it was forced to use civilian personnel for much of its electronic maintenance work. The DEW Line, for example, is almost completely staffed by contractor personnel.

Among the major tasks performed by contract personnel was maintenance of the SAGE(AN/FSQ-7) computers. In 1956, International Business Machines Corporation (IBM) was awarded the job of maintaining the computers. In one respect, SAGE computer maintenance was a special case; because digital computers were new to the Air Force, there existed no Air Force career field airmen trained to maintain them, much less enough men qualified to maintain twenty-five of the biggest duplex computers ever built.

Contractor maintenance kept the machines running, but it had drawbacks. High cost was one, though it probably was not as serious as some have suggested. Another was the harmful effect on the military operators' morale of working with men being paid more and not subject to military restrictions. However, the biggest problem to the Air Force was the question of control: what would happen if war broke out and the contract technicians went to their families rather than to their duty station? In effect, the Air Force appeared to have become dependent on men over whom it had no reliable control in time of war. Consequently, pressure mounted in high Air Force levels to arrest or reverse the trend to maintenance by contract.

"BLUE SUIT" COMPUTER MAINTENANCE

In late 1958, the Air Defense Command (ADC) drew up a plan for military maintenance of the SAGE computers. * The stated goals of the plan were to establish military control over the maintenance activities and to reduce the cost of SAGE computer maintenance. On the vital question of the capability of Air Force technicians to perform computer maintenance effectively, ADC had received assurance from IBM that the airmen could do the job. The other major concern – whether enough qualified airmen were available to maintain all the SAGE computers – was a matter of judgment on the part of the Air Force. Air Force Headquarters evidently felt that there were enough, and in January 1959 authorized ADC to carry out its plan.

The overall structure of the ADC plan rested firmly on the pattern set by IBM maintenance. In many particulars, the statistical card room, the training program, the maintenance handbooks and procedures, and the supply program, the IBM pattern was unchanged, even to retaining direct IBM manning. In the remainder of the plan, the technician job classification structure, the shift manning and rotation practices, and the manning levels, the IBM pattern was used, with Air Force technicians replacing the IBM personnel.

The specific manning indicated in the ADC plan reflected both the IBM manning structure prevailing when the plan was set up, and a body of Air Force beliefs on maintenance manning requirements that appeared reasonable. The ADC complement was set at 58, 5 officers and 53 airmen, based on the 58 men IBM used in 1958 to do the SAGE computer maintenance job. **^[1] In addition

* Hq. Air Defense Command letter to HQ USAF, September 18, 1958; Subject: SAGE Computer Maintenance Proposal.

** In our analysis we have focused solely on airmen population. None of our studies is concerned with the officers.

to the military maintenance group, the ADC plan specified 13 IBM technicians at each site for technical support. Although the reasoning underlying this support was never formally stated, the consensus is that the function of the back-up is to provide continuity in the face of military turnover, to smooth out manpower available in the face of assumed military assignment fluctuations, and to fill in for the assumed difference in maintenance quality between the 58 IBM men and the 58 ADC men assigned to each site. Further, to ensure that ADC would have enough qualified men available at each site, the plan specified an unusually high proportion of experienced personnel; the proportion of experienced men authorized at each site was more than double the proportion prevailing in the electronics maintenance career field as a whole. [2] Finally, the plan called for ADC to take over maintenance of the SAGE computers at the rate of, roughly, one site every two months. The problem here was that, if the implementation proceeded on schedule, a larger number of experienced military technicians would be required than could be provided without seriously reducing the experience level throughout the rest of the Air Defense Command.

WAADS - THE PILOT SITE

Since the success of the ADC plan rested on a number of uncertainties, it was decided to try the plan out at one site before full scale implementation of the plan had proceeded too far through the SAGE system. In this way, plan modifications could be made on the basis of information fed back from the pilot site. In addition, should the pilot site experience indicate in any way that the ADC plan was unfeasible, a return to contract maintenance could be made with a minimum of detriment to SAGE operations.

The Washington Air Defense Sector (WAADS) was chosen as the pilot site. The MITRE Corporation was selected to conduct the evaluation. The period set for the evaluation was from November 1959 to August 1961; from the date that the first ADC airmen began training in computer maintenance at the IBM school in Kingston, New York, until these airmen had completed one full year of computer maintenance at WAADS.

The overall evaluation plan and the specific questions to be asked were obvious from the nature of the ADC plan. The central focus had to be on an input-output analysis of computer maintenance at WAADS: the ADC and IBM technicians assigned to WAADS to maintain the computer would be compared; the ADC and IBM maintenance performance at WAADS would be compared. Data from the remainder of the sites of the 26th Air Division of SAGE would be used to provide comparison data with which to substantiate the conclusions drawn from the WAADS data. Finally, on the assumption that the maintenance effectiveness at any site was a function of the technicians at that site, the ADC technicians would be checked against the overall ADC technician pool from which they were drawn and against the ADC technicians selected for the sites to be manned after WAADS.

In this way, questions then being asked about the ADC plan could be answered. How did the ADC technicians selected for WAADS compare with those IBM had been supplying? If there were differences between the IBM and the ADC technicians, how would they be reflected in the effectiveness with which the computers were maintained? How would the Air Force technicians selected to maintain the other SAGE computers compare with those selected to maintain WAADS? Finally, what measures should be used to evaluate the performance of technicians maintaining the computers, and how should the effectiveness of computer maintenance at a SAGE site be measured?

THE EVALUATION PLAN

To compare the IBM and ADC men, standard psychometric data were used to measure technicians' effect on SAGE maintenance. An intelligence test, tests of electronics knowledge, and tests of reasoning ability had been given to all IBM technicians as part of the IBM pretraining selection procedure. These test data were supplemented by the training grades given in the IBM training course. The validity of these test data and training scores had been verified by IBM studies comparing them with on-site supervisory performance evaluations. These studies showed a high correlation between the data and the performance evaluations. Arrangements were made for IBM to use with the WAADS airmen the identical tests and training standards that had been used with IBM technicians.

Measuring the effectiveness of maintenance rested on the performance reliability data from the SAGE computer operations. It would be expected that the higher the computer reliability, the higher the maintenance effectiveness of the technicians. However, the fact that the SAGE computers at each site were duplexed, and that the nonactive (standby) computer at a site might be operating in a number of different modes that could affect the down time, left open the possibility that this generalization might not be true for SAGE computer maintenance. [3] Therefore it appeared necessary to develop a method of analyzing the site computer reliability data in a manner that would make it possible to isolate for each time period the particular modes in which the standby computer was operating and the time that it was in each mode. It was also necessary to remove from the comparison those data that reflected situations over which the maintenance technicians had no control but which might affect the reliability of the computer, especially periods of major retrofit activity on the computer. (For an extended discussion of SAGE duplex computer reliability, see reference 4.) With these data and these checks on the data determined, a comparison

could be made between IBM maintenance of the WAADS computer for the one-year period immediately previous to ADC assumption of maintenance and the computer performance at WAADS for the one-year period of ADC maintenance.

It was then necessary to determine that there was nothing unusual about the particular year at WAADS during which the ADC technicians were maintaining the computer and that there was nothing unusual about the manner in which the reliability data had been gathered and reported during this period. To check the WAADS data on the first point, comparable data for four other sites (Bangor, New York, Syracuse and Sault Ste. Marie Air Defense Sectors) were analyzed for the same time period as that of ADC maintenance at WAADS. To assure that the data collected and reported by WAADS and other sites for the period of ADC maintenance were accurate, two MITRE representatives, one of whom had taken the IBM computer maintenance course with the WAADS group, were assigned to WAADS from April 1960 to June 1961 and worked on the analysis of site reliability data.

Finally, given the input-output comparisons from WAADS, one question remained: how did the WAADS technicians compare with those that one could expect to find doing SAGE computer maintenance at future sites? The first requirements here were measures truly reflecting individual maintenance performance. Since SAGE computer maintenance was a group activity, no objective individual performance measures were available. The only recourse, and one valid theoretically, was to obtain subjective evaluations of the performance of each technician at WAADS. The evaluation technique chosen was one in which each technician was evaluated by each of his peers and by at least two supervisors. This technique produced composite measures of the performance effectiveness of each technician. These composite performance measures were correlated with previously obtained data on aptitude, intelligence, training

performance, age, time in service, time in the electronics maintenance field, and grade level to determine which factors appeared to predict individual maintenance effectiveness most accurately. With these predictors, it remained only to compare the WAADS technicians with technicians sent by ADC to maintain SAGE computers at other sites and with the pool of men available to ADC for maintaining other SAGE computers in the future. This comparison would indicate how well ADC would maintain the rest of the SAGE computers.

ADC COMPUTER MAINTENANCE: THE FIRST YEAR

Unique Conditions at WAADS

The first year of ADC computer maintenance was performed at WAADS from 1 August 1960 through 31 July 1961. Any estimates of how well ADC technicians can be expected to maintain computers in the future use the experience of this period as the basis of prediction; but the manpower provisions for computer maintenance at WAADS were in certain significant respects different from what can be expected to be the case in the future.

Some of the differences tended to give WAADS less favorable manning. WAADS had, by definition, a group less experienced in computer maintenance than will ever again prevail at a SAGE site under military maintenance. Specifically, two basic levels of technicians make up the maintenance crews: "units" technicians, whose training and experience are limited to either the central computer, the input-output equipment, or the display equipment; "systems" technicians, drawn from the better "units" technicians, who have advanced training and experience in maintenance of the overall computer system. The WAADS group at no time had any ADC systems technicians. Further, to provide systems technicians for future site manning, ten of the best WAADS units

technicians were sent from WAADS to IBM for system training in February 1961 and were not returned to the site until June 1961. (See Appendix D)

The differences that may have tended to favor the WAADS manning are not so concrete. Primary among these is the fact that WAADS was assigned all the men it was authorized. This situation, 100 percent manning, is not characteristic of current SAGE manning in other areas of electronic maintenance activity (e. g. radar and communications), and most observers acquainted with the ADC personnel/manpower situation believe that future manning levels in computer maintenance will probably stabilize in the area of 60 to 80 percent manning of authorized levels. The other major difference that may have favored the WAADS performance was that all the technicians and supervisors knew that WAADS was in the spotlight, and therefore reasonably might be expected to perform better than if they were not working under experimental conditions.

Personnel Input to WAADS

What kind of men were assigned to WAADS? By and large, ADC sent as good a group to WAADS as it could send, though these men were not equivalent to the IBM men that they replaced. Comparing the WAADS group with the ADC career field group from which they were selected showed that the WAADS group had more maintenance experience, a higher average electronics aptitude, and a higher average grade level. [2]

Since aptitude and experience are traditionally the means of identifying the best technicians in the Air Force, it seems clear that ADC had fielded one of its best teams for WAADS. But, as ADC had expected, these men did not measure up to the IBM men. In terms of electronics knowledge, reasoning ability, general intelligence, and training performance, the WAADS group measured significantly lower (at the .001 level) than the IBM men then assigned to computer maintenance in the 26th Air Division of SAGE as shown in Table I.

• Table I
Comparative Test Results of WAADS and IBM Technicians

	WAADS (N = 54)		IBM (N = 214)	
	\bar{x}	σ	\bar{x}	σ
Electronics Knowledge	33	6.6	40	3.7
Reasoning Ability	37	6.9	45	3.4
Intelligence	110	9.1	122	6.5
Examination Average	69	12.6	79	7.2
All differences significant at the .001 level. [2, 5]				

Maintenance Output from WAADS

Since the ADC maintenance personnel assigned to WAADS (the inputs) appeared less capable on the average than the IBM men that they were replacing there was uncertainty about what would happen to the reliability of the SAGE computer. Surprising to many, SAGE computer reliability at WAADS remained at the same high levels established when IBM performed the maintenance. Perhaps of even greater surprise to many was the fact that the ADC maintenance performance was in no apparent way hurt when the ADC WAADS group lost nearly 20 percent of its best technicians in the February-June 1961 period. The reliability data are given in Table II.

When presented with an apparent anomaly such as inputs having no correlation with outputs, a logical first step is to check the data; in this case the reliability data. Had the data been accurately recorded? They had. Had the ADC WAADS maintenance been performed under a markedly more favorable pattern of operating modes of the standby computer? It had not. Was there

something operating from August 1960 through July 1961 that made the WAADS computer intrinsically more reliable than it had been previously? Nothing in the reliability data from other SAGE computers for this period lent support to the notion of increased intrinsic reliability, nor was there any major engineering change in the WAADS computer to which an increase in intrinsic reliability could be attributed.

Table II
Comparative Reliability Data for WAADS*

	IBM		ADC	
	1959	1960	1960	1961
	5 mo.	7 mo.	5 mo.	7 mo.
Percentage of Time Computer was Available	99.89	99.88	99.81**	99.96**
Mean Hours to Failure	22.10	31.61	27.65	37.40
Mean Hours to Repair	0.17	1.47	1.06	1.03
Unscheduled Maintenance as a Percentage of Total Time	3.03	4.52	3.65	2.72

*See Appendix C.

** A corresponding shift in computer availability from 99.81 to 99.97 occurred at SSMADS (Sault Ste. Marie Air Defense Sector) during the same period. This similarity is significant, since SSMADS became operational at the same time that the ADC group assumed maintenance responsibility at WAADS. It then seems that this shift at both WAADS and SSMADS can be attributed to the same cause, the learning that occurs as a new maintenance group becomes familiar with its job.

The Meaning of the Data

If the data and conclusions were accurate, perhaps something was wrong in the premises that led to the belief that maintenance manning inputs ought always to be correlated with machine reliability outputs. In the case of WAADS computer maintenance, the premises that were faulty were so fundamental and so implicit in the ADC plan that no one had ever really questioned them. These premises concerned the number of maintenance men needed and the level of their capabilities. The principal error in these premises resided in the difference between the difficulty of the maintenance job required for the SAGE computers in 1958 and the difficulty of the maintenance job in 1961.

In August 1958, when the ADC plan for SAGE computer maintenance was written, IBM had far less maintenance experience with the SAGE computer than it had, for example, in January 1961, when ADC was maintaining the computer according to the manning structure of the ADC plan. This difference in experience and knowledge was reflected in the number of men that IBM required to maintain each computer*, as shown in Fig. 1.

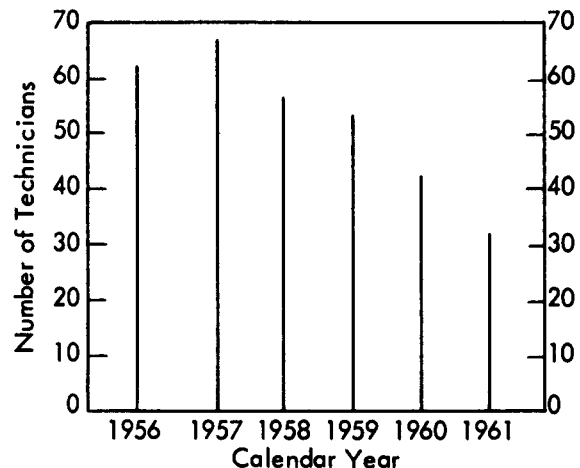


Fig. 1 IBM SAGE Manning Experience

*Letter of January 17, 1962, from D. Simek (IBM) to H. W. Adams

The job of AN/FSQ-7 maintenance had become simpler than the ADC plan had assumed it to be; that is, when the ADC plan was written, SAGE computer maintenance was a 58-man job; when the plan was put into effect, it had become a 42-man job, and is now a 32-man job. The change in job difficulty came about because the IBM experience was translated into simplified maintenance and diagnostic procedures that were incorporated into on-site training programs, improved maintenance manuals, and improved diagnostic maintenance programs.

Thus, the apparent contradiction of the better IBM inputs having no noticeable correlations with WAADS reliability output is understandable. The WAADS experience showed that 53 ADC men with IBM back-up and very little experience could keep the computer running during the August – December 1960 period about as well as 48 IBM men had done during the previous year. The WAADS experience from February through June 1961 showed that 42 ADC men with IBM back-up and some experience could keep the computer running as well as IBM had ever done. Further, on the point of manning levels, of the IBM men assigned to back up the ADC men, the workload data indicated that even in peak periods there was only enough work for about ten men,^[6] though an average of 15 IBM men were assigned as back-up from August 1960 through July 1961. (See Appendix B)

The following conclusions were made about site manning requirements:

- (a) 53 inexperienced ADC men with 17 IBM back-up men perform SAGE computer maintenance satisfactorily.
- (b) 42 semiexperienced ADC men with 15 IBM men and no system technicians performed the computer maintenance job as well as IBM technicians did at other sites (from February through June 1961).

- (c) In case (b) above, the same results could probably have been produced with 5 fewer IBM men.
- (d) If the ADC men included men with system training, one would expect that fewer than 42 ADC men, given 10 IBM back-up men, could do a satisfactory job of SAGE computer maintenance.

FUTURE SITE MANNING

ADC has selected technicians for three sites in addition to WAADS: the New York, Boston, and Syracuse sectors (NYADS, BOADS, and SYADS). If the qualifications of these groups imply as good maintenance for their sectors as the WAADS group did for WAADS, and if ADC has enough qualified men to populate the rest of the SAGE sectors in similar fashion, then we feel confident that military maintenance of SAGE is feasible.

The NYADS, BOADS, and SYADS groups do appear to have the qualifications necessary for maintaining computer performance at reliability levels equal to those that ADC achieved at WAADS. In a previous study^[7] it was shown that the following qualifications of the WAADS group were significantly correlated with maintenance effectiveness: the technicians' average in IBM training, and their scores on the electronics knowledge test and the Otis intelligence test, both administered by IBM. Valid comparative data for WAADS and the other sites are available for the electronics knowledge and intelligence measures and are given in Table III.^[8] These data show no significant differences among the four site populations.

Table III

Comparative Test Scores of ADC Technicians at WAADS and Follow-On Sites

	WAADS	NYADS	BOADS	SYADS
Number	53	55	55	56
Electronic Knowledge (Average)	33.3	33.9	33.6	33.8
Intelligence (Average)	110.2	107.8	108.1	109.8

The examination averages for WAADS cannot be compared with those for the other three sites, since the content and number of questions in the WAADS examinations were different from those in the NYADS, BOADS, and SYADS examinations.

Although there are no important differences in terms of probable maintenance effectiveness, the WAADS group was different from the other three. Briefly, the WAADS group was made up of far scarcer ADC airmen than were the NYADS, BOADS, and SYADS groups. As shown by Table IV, the WAADS group was drawn from perhaps the scarcest manpower resource in the Air Force; experienced, high-ranking electronics technicians. ^[9]

Table IV

Qualifications of ADC Technicians at WAADS and Follow-On Sites

	WAADS	NYADS	BOADS	SYADS
Percent having completed first tour of duty	96	78	56	67
Percent Staff Sergeant or higher	78	55	36	45
Percent from electronics maintenance career field	94	76	72	78
Average years of communications-electronics experience	8.9	5.8	3.5	4.6

Overall, then, the Air Defense Command has selected, for the follow-on sites, men who are not in such critically short supply as those who went to WAADS but who should do as good a job of computer maintenance as the WAADS group did. More simply, ADC has provided as much potential maintenance but at a lower cost.

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1. Smith, C.D. , "Observations of AN/FSQ-7 Maintenance Activities," MITRE W-2564, 14 October 1959.
2. Adams, H.W. , A.S. Morton, and F.P. Gatling, "Personnel Inputs of IBM, WAADS, and ADC Technicians Compared," MITRE TM-2797, 17 June 1960.
3. Gold, J. , "Estimation of Duplex Computer Reliability from Simplex Data," IRE Conference Proceedings on Military Electronics, 1959, pp. 385-390.
4. Adams, H.W. and A.S. Morton, "Project Headstart - SAGE Computer Maintenance Evaluation Criteria," MITRE W-3482, 12 December 1960.
5. Morton, A.S. , "Analysis of Field Engineering Training Measures," MITRE TM-2847, 13 September 1960.
6. Pacine, L.G. , and J.H. Proctor, "Maintenance Organization, Manning and Functions," MITRE W-3806, 23 March 1961.
7. Morton, A.S. and I.W. Miller, Jr. , "Selecting Military Maintenance Personnel for the AN/FSQ-7 Computer," MITRE TM-3049, 21 April 1961.
8. Morton, A.S. , P.A. Finn, and L.G. Pacine, "ADC Computer Maintenance; WAADS, NYADS, BOADS, SYADS," MITRE W-4639, 25 January 1962.
9. Adams, H.W. , "ADC Maintenance of SAGE Computers - Current Status," MITRE W-257, 13 May 1959.

APPENDIX A

ANNOTATED BIBLIOGRAPHY OF MITRE HEADSTART PUBLICATIONS

1. NORAD Description and Manpower Requirements for 1960-1965;
Carla-Mae Festa, TM-2589, December 30, 1959. (Secret)

A description of the NORAD system as of 1960 and 1965, with an overview of the system, and a detailed estimation of the manpower requirements of the system for these time intervals.

2. USAF Contract vs. Military Manning Potential: NORAD Electronic Technicians, 1959-1965; H. W. Adams, TM-2663, March 1, 1960.
(Confidential)

A study of the availability of experienced technicians proportional to NORAD manpower requirements. The conclusion is reached that the supply of experienced technicians proportional to demand cannot be expected to increase during this period.

3. ADC Maintenance of SAGE Computers - Current Status; H. W. Adams, W-257, May 13, 1959.

The ADC plan for assumption of SAGE computer maintenance responsibility is discussed, as well as IBM experience in maintaining the computers, the IBM personnel and organization patterns, and the assumptions underlying the ADC plan.

4. Evaluation of ADC SAGE Computer Maintenance Plan: Project Headstart; H. W. Adams, W-472, August 31, 1959.

The decision for early implementation of the ADC plan at the Washington Air Defense Sector (WAADS) to evaluate the ADC computer maintenance plan is indicated. Also indicated are points of apprehension about the realism of the plan. In addition, an overview of Project Headstart objectives, the evaluation of the ADC plan based on the WAADS experience, is given.

5. Observations of AN/FSQ-7 Maintenance Activities; C. D. Smith, W-2564, October 14, 1959.

Observations of actual IBM maintenance activities are recorded concerning the organization, manning, job descriptions and methods of operation of a typical IBM SAGE sector maintenance activity.

6. ADC Electronic Technicians: Aptitude Level Distribution; Linda T. Sprague, W-2555, October 20, 1959.

A preliminary report on a study of the quality level of the airmen in ADC who formed the population from which men were to be drawn for SAGE computer maintenance. The conclusions were that, over-all, the airmen had a high aptitude level and that the aptitude level of the more experienced technicians tended to be higher than that of the less experienced men.

7. Project Headstart; H. W. Adams, TM-2516, October 29, 1959.

Agreements reached by MITRE, HQ USAF, HQ ADC, HQ 26th Air Division (SAGE), HQ WAADS, HQ AMC, HQ ATC and IBM at a meeting held October 13-15 concerning the evaluation plan for Project Headstart are detailed.

8. Analysis of ADC Electronic Technician Aptitude; Linda T. Sprague, TM-2676, March 25, 1960.

A final report on the aptitude level distribution of ADC electronic technicians previously reported in W-2555. The conclusion is reached that the technicians re-enlisting tend on the average to have a higher electronics aptitude than those leaving the service. The data used here covered a complete enumeration of the pertinent categories of the 30XXX career field in 1959.

9. Personnel Inputs of IBM, WAADS and ADC Technicians Compared; H. W. Adams, A. S. Morton, F. P. Gatling, TM-2797, June 17, 1960.

The aptitude and intelligence scores and training grades of IBM computer maintenance technicians of the 26th Air Division (SAGE), of ADC airmen assigned to WAADS, and of the ADC pool of maintenance technicians from which the WAADS groups was drawn are analyzed. It is concluded that the WAADS technicians display less potential competence than the IBM men they are replacing, but more competence than could be expected from a random selection among ADC maintenance technicians.

10. Selecting Computer Maintenance Technicians: Preliminary Report; A. S. Morton, H. W. Adams, F. P. Gatling, TM-2819, August 1, 1960.

Using aptitude, intelligence and training data, a method of selecting airmen for computer maintenance is suggested which would optimize training performance of those selected. This report is superseded by TM-3049.

11. What Does an Airman Cost ?; Carla-Mae Festa, H. W. Adams, W-3138, August 12, 1960.

Based on HQ USAF, RAND and Congressional Hearings data, the cost of electronic technicians is estimated to be at least \$7500 annually per man in the United States and \$7800 overseas.

12. Analysis of Field Engineering Training Measures; A. S. Morton, TM-2847, September 13, 1960.

The grades given in the IBM computer maintenance course are examined for the WAADS group and for a representative group of IBM student technicians. It is concluded that the examination grades are the most meaningful grades, and that the WAADS technicians were graded according to the same standards as the IBM students.

13. Selection for AN/FSQ-7 Maintenance: 301XX, 303XX, 304XX AFS Compared; H. W. Adams, Carla-Mae Festa, TM-2891, November 2, 1960.

In response to a request from HQ USAF, the training performance of the WAADS group is examined to see whether the man's previous position classification was significantly related to training performance. It was determined that the only significant performance differences were among airmen selected from the 3015X classification. (This difference has since been shown to be insignificant in terms of on-the-job performance.)

14. SAGE Computer Maintenance Evaluation Criteria; H. W. Adams, A. S. Morton, W-3482, December 12, 1960.

A method for evaluating the effectiveness of maintenance of the SAGE computers is developed. Based on reliability data from a single site and control data from similar sites, it is shown that maintenance performance as a variable can be isolated from other factors affecting computer reliability data.

15. The AN/FSQ-7 Computer Operator Position; W. J. Vibbard, TM-2956, January 17, 1961.

The duties and function of the "computer operator" position at a SAGE sector are examined. It is concluded that the position is simply that of the computer console coordinator and should properly be assigned to the computer maintenance activity at the sector, rather than to the maintenance analysis activity as had been the case. It was further recommended that the manning for this position be drawn solely from technicians trained in computer maintenance.

16. Maintenance Organization, Manning and Functions; L. G. Pacine, J. H. Proctor, W-3806, March 23, 1961.

An analysis is made of the position duties, manning, and organization of the SAGE computer maintenance activities. The recommendations made are that the WAADS pattern of organization be followed at future sectors, that more study be done of the proper mixture of airmen technicians and IBM support, and that certain changes in the position of the IBM site manager be made at future sectors when ADC assumes maintenance responsibility.

17. Selecting Military Maintenance Personnel for the AN/FSQ-7 Computer; A. S. Morton, I. W. Miller, Jr., TM-3049, April 21, 1961.

An analysis is made to determine the maintenance performance effectiveness of the individual technicians of the WAADS group. Correlations are done to determine those factors in the individual's background which best predict maintenance performance effectiveness. It is concluded that the only significant predictors are the individual's course training grades, his intelligence level, and his electronics knowledge test grade. Experience, aptitude, military rank, age and reasoning ability were found to have no significant correlation.

18. Military vs. Contract Maintenance of the AN/FSQ-7; H. W. Adams, A. S. Morton, W-3887, April 20 1961.

A summary report of the findings of the first six months of military maintenance of the WAADS computer. The tentative conclusions are reached that ADC maintenance will probably be satisfactory, and that both ADC and IBM manning levels could be reduced without detriment to machine reliability.

19. Mean Time To Failure — A Measure of Intrinsic Reliability of AN/FSQ-7 Computers?; W.S. Rouse, W-3817, March 28, 1961.

Reliability data from five SAGE sectors are analyzed. The conclusion is reached that the mean time to failure of the computers is not a measure of their intrinsic reliability alone, but is significantly affected by differences in the manner in which the machines are maintained and used.

20. AN/FSQ-7 Contractor Technician Assistance Requirements; L. G. Pacine, H. W. Adams, J. H. Proctor, TM-3105, July 5, 1961.

Data on IBM assistance to ADC technicians at WAADS are analyzed. It is concluded that the work to be done could just as well be done by 10 IBM technicians, rather than the 13 specified in the ADC plan or the 15-17 assigned to the WAADS sector.

21. Airman Assignment Accuracy; J. H. Proctor, W. S. Rouse, TM-3106, July 5, 1961.

Data from the ADC 26th Air Division (SAGE) are analyzed to determine how well the Air Force assigns airmen to the jobs in which they can, by Air Force definition, do the most for the Air Force. It is concluded that assignment accuracy runs between 83 percent for the more highly technical career fields and 91 percent for the less highly technical career fields. The computer program used to analyze airmen assignment data is indicated.

22. ADC Computer Maintenance Men: WAADS, NYADS, BOADS, SYADS; A. S. Morton, W-4639, January 25, 1962.

Various characteristics of the computer maintenance technicians assigned to the first four sites maintained by ADC airmen are analyzed. It is concluded that the men assigned to the three sites after WAADS should perform as well as those assigned to WAADS, and that the men at the follow-on sites do not draw as heavily on the scarce personnel resources of the Air Force as did the WAADS group.

APPENDIX B

AN/FSQ-7 CONTRACT TECHNICIANS

The ADC plan of August 1958 for assuming the maintenance responsibility of the SAGE AN/FSQ-7 computer provided for 5 officers, 53 airmen, and 13 IBM contract technical services (CTS) personnel at each site to handle the maintenance tasks.

The role of the CTS personnel was to provide technical assistance as required and to provide a measure of continuity of knowledge which could not be guaranteed by the Air Force because of its rotation policies.

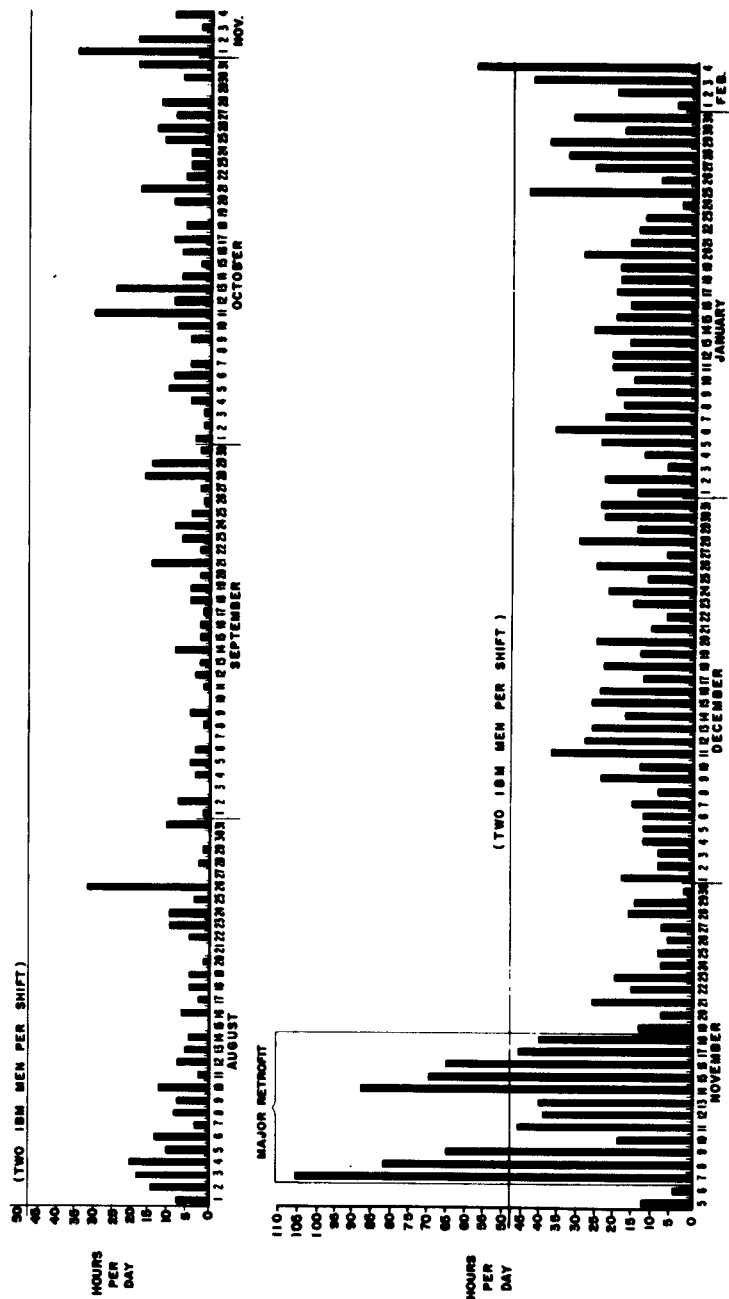
Data on the amount of time spent by CTS personnel in maintenance assistance at WAADS from 1 August 1960 through 31 May 1961 is summarized in the Table V.

Fig. 2 illustrates the amount of assistance provided daily by the CTS personnel during this period.

Table V

Summary of Reported Assistance Time (Hours)

	Central Computer	Display	Input- Output	Total	Certified Man Hours	Percent of Recorded Time Spent in Assistance
Aug.	120.2	46.2	54.4	220.8	2832	7.8
Sept.	39.3	52.5	25.8	117.6	2696	4.4
Oct.	74.0	105.5	58.4	237.9	2656	9.0
Nov.	390.5	485.0	70.7	946.2	2744	34.5
Dec.	257.4	160.5	128.0	545.9	2784	19.6
Jan.	136.2	423.6	79.4	639.2	2912	22.0
Feb.	291.4	236.1	287.4	814.9	2672	30.4
Mar.	394.5	495.4	183.5	1073.4	2992	35.9
Apr.	265.1	541.9	150.2	957.2	2677	35.8
May	<u>434.3</u>	<u>575.5</u>	<u>338.8</u>	<u>1348.6</u>	<u>2867</u>	<u>47.0</u>
	2402.9	3122.2	1376.6	6901.7	27,832	24.8
Percent of total	35	45	20			



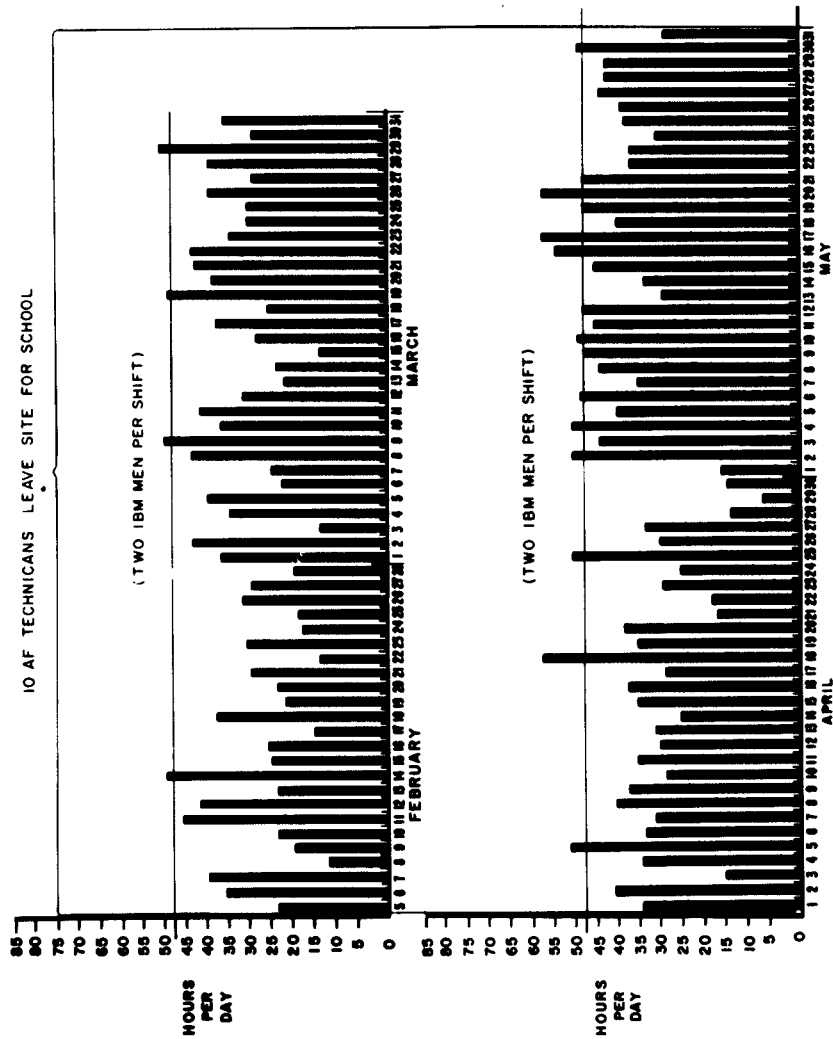


Fig. 2 IBM Assistance to ADC Technicians

APPENDIX C

AN/FSQ-7 RELIABILITY DATA

The data used in MITRE's evaluation of maintenance effectiveness were collected directly from the AN/FSQ-7 operations logs. The operations logs are daily reports that list the status (active or standby) and condition (performing air defense, not performing air defense, scheduled maintenance, unscheduled maintenance, etc.) of each of the computers, and the length of time spent in a particular status condition. As the status and/or condition changes, new log entries record the change.

The basic approach used in the data collection was to reduce 48 hours of computer operations per day (24 hours per computer) to 24 hours of system operation. The system operating time was subdivided according to mode of operation. Periods of extended retrofit were excluded. (Extended retrofit is defined as a retrofit whose duration is such that it requires the shut-down of the active computer for preventive maintenance -- in general, a retrofit of at least a 40-hour duration.) In any particular mode of operation, one computer is running the active air defense program while the other computer, the standby, is engaged in one of the following functions:

Mode A: The standby computer is cycling a program (DCS) which permits immediate switchover to active air defense.

Mode B: The standby computer is running a program or being used for some purpose other than as back-up for the active computer.

Mode C: The standby is in scheduled maintenance.

Mode D: The standby is in unscheduled maintenance.

Mode E: The standby is in retrofit.

Computer system time was distributed among the various system modes, generally following the coding used in the operations log.

Having determined the method for tabulating reliability data, the next point was to determine how to derive a measure of maintenance effectiveness from these data. It was first necessary to isolate those effects due to causes other than maintenance from those properly attributable to maintenance. The maintenance correlated measures were those associated with periods of Lost Air Defense (LAD) on the active computer, or a period of unscheduled maintenance on the standby computer. In both cases, the cause of the unforeseen computer status was a computer failure: a failure was therefore defined as a computer malfunction such that the on-going function of that computer must be interrupted. Since the function of the maintenance activity is to prevent such unforeseen interruptions, the occurrence of a failure isolates maintenance ineffectiveness, thereby measuring in inverse fashion the effectiveness of maintenance.

Using the mode distribution of system time, the next step was to isolate the amount of LAD time attributable to maintenance. The amount of time that ~~air defense was being~~ performed was checked. If the total did not equal 24 hours, the logs were checked for the reason. LAD due to nonmaintenance factors; e.g., program change, simulated noplex, or external power failure was considered good time. LAD resulting from a computer failure was then checked and each occurrence was designated by tallying one failure and recording the amount of LAD. Further, the mode of operation in which the failure occurred was recorded and the length of LAD time was subtracted from the amount of time that the standby spent in that mode.

Next, the periods of unscheduled maintenance were checked. Each period of unscheduled maintenance that was followed and preceded by a period of something other than unscheduled maintenance was designated as representing one failure, unless LAD immediately preceded the unscheduled maintenance. In that case the failure already had been recorded. It should be noted again that the parameters used in our evaluation are based on system performance; therefore, no distinction is made between computers, or between active computer and standby computer failures.

From this point the data reduction was straightforward. The daily worksheets were summed and the information is listed in Table VI (the parameters MTF and MTR are explained below).

The time over which the data were collected was then divided into four periods, with the major division corresponding to the day that ADC assumed maintenance responsibilities at WAADS (1 August 1960). The periods are as follows:

Period 1 (IBM) 1 August 1959 — 2 January 1960

Period 2 (IBM) 3 January 1960 — 31 July 1960

Period 3 (ADC) 1 August 1960 — 31 December 1960

Period 4 (ADC) 1 January 1961 — 31 July 1961

WAADS data were gathered for all four periods to give data for one full year of IBM maintenance and for one full year of ADC maintenance. BAADS, SYADS and NYADS data were collected for the same one-year period of ADC-WAADS maintenance and for the period just previous to this. SSMADS became operational on 15 July 1960, and data were collected for the period during which ADC maintained the WAADS computer. Tables VII through X were then prepared from the data in Table VI. Table XI was prepared from data in Table VI plus Mode B time.

WAADS										BAADS					
REPORT PERIOD	HOURS ¹	NO. OF FAILURES ²	MTF	UNSWA ³	LAD	MTR	MODE A TIME ⁴	HOURS	NO. OF FAILURES	MTF	UNSWA	LAD	MTR	MODE A TIME	
1959	8/1 - 8/15	360	18.94	10.13	.07	.54	44.00								
	8/16 - 9/12	672	30.54	12.63	.22	.58	69.31								
	9/13 - 10/10	432	20.54	12.39	.58	.62	48.30								
	10/11 - 11/7	—	—	—	—	—	—								
	11/8 - 12/5	408	19.38	15.50	1.05	.79	49.57								
12/6 - 1/2	672	32	20.97	27.82	.82	.90	103.30								
1960	1/3 - 1/30	672	10	67.10	2.04	.98	.30	32.17	672	10	67.20	8.23	—	.82	156.83
	1/31 - 2/27	672	20	33.55	6.75	1.09	.39	51.59	672	10	67.20	6.76	—	.68	148.79
	2/28 - 3/26	672	27	24.86	27.60	.73	1.05	40.95	672	14	47.98	44.18	.33	3.18	78.32
	3/27 - 4/23	672	27	26.86	55.65	.38	2.24	101.53	672	13	51.66	10.04	.45	.81	97.56
	4/24 - 5/21	672	15	39.52	58.34	.15	3.44	45.49	672	6	111.97	2.94	.15	.52	126.98
	5/22 - 6/18	672	24	27.97	18.19	.78	.79	33.01	672	12	55.94	5.89	.68	.55	159.17
	6/19 - 7/16	672	21	31.94	18.35	1.25	.93	72.36	672	14	48.00	15.68	—	1.12	83.47
	7/17 - 7/31	360	16	22.47	42.21	.49	2.67	28.00	360	5	72.00	7.70	—	1.54	99.71
	8/1 - 8/13	312	16	19.46	28.80	.68	1.84	16.14	312	8	39.00	31.42	.01	3.93	38.65
	8/14 - 9/10	672	33	20.29	37.04	2.36	1.19	118.42	672	10	67.16	6.25	.37	.66	62.70
9/11 - 10/8	672	22	30.54	14.85	.05	.68	85.67	672	1	672.00	2.42	—	2.42	97.34	
10/9 - 11/5	672	23	29.08	23.17	3.11	1.14	112.67	672	6	111.98	2.49	.12	.44	121.27	
11/6 - 12/3	408	9	45.31	5.02	.20	.58	72.31	456	4	113.96	5.25	.14	1.35	101.51	
12/4 - 12/31	672	20	33.59	15.40	.15	.78	64.20	672	7	96.00	9.85	—	1.41	111.84	
1961	1/1 - 1/28	672	12	55.98	19.74	.20	1.66	51.95	672	10	67.18	4.63	.24	.49	77.62
	1/29 - 2/25	672	15	44.79	36.51	.15	2.44	75.87	672	9	74.64	4.70	.28	.55	129.17
	2/26 - 3/25	672	24	27.99	15.74	.15	.66	47.53	672	7	96.00	7.47	—	1.07	87.20
	3/26 - 4/22	672	12	55.97	11.85	.38	1.02	42.55	672	21	31.97	21.70	.57	1.06	108.42
	4/23 - 5/20	672	15	44.80	7.90	.07	.53	22.69	672	5	134.38	2.31	.12	.49	59.65
	5/21 - 6/17	672	17	39.51	12.98	.36	.78	17.74	672	8	83.98	4.39	.15	.57	80.31
	6/18 - 7/15	672	28	23.99	21.35	.40	.78	41.65	672	13	51.67	7.93	.30	.63	111.43
	7/16 - 7/31	384	13	29.53	12.25	.12	.95	8.70	384	5	76.76	2.97	.19	.63	47.59

1. HOURS: TOTAL NUMBER OF HOURS IN THE TIME PERIOD (PERIODS OF EXTENDED RETROFIT EXCLUDED.)

2. NO. OF FAILURES: TOTAL NUMBER OF INTERRUPTING FAILURES.

3. UNSWA: HOURS OF UNSCHEDULED MAINTENANCE.

4. MODE A TIME: NUMBER OF HOURS THE SYSTEM WAS IN MODE A.

	SYADS							NYADS							SSMADS						
	HOURS	NO OF FAILURES	MTF	UNSM A	LAD	MTR	MODE A TIME	HOURS	NO OF FAILURES	MTF	UNSM A	LAD	MTR	MODE A TIME	HOURS	NO OF FAILURES	MTF	UNSM A	LAD	MTR	MODE A TIME
1959																					
1960	672	21	31.90	8.48	2.03	.50	129.35	672	30	22.39	19.92	.40	.68	37.82	312	13	23.82	8.20	2.30	.81	60.10
	672	27	24.85	8.30	.99	.34	88.57	672	46	14.60	58.61	.20	1.28	27.17	672	12	56.00	46.45	—	3.87	158.60
	672	14	47.99	30.51	.08	2.19	74.32	672	14	47.98	28.58	.23	2.06	78.31	672	11	61.08	13.75	.10	1.26	141.70
	672	11	61.05	3.56	.43	.36	69.66	672	26	25.83	34.40	.42	1.34	101.29	672	27	24.74	31.50	4.05	1.32	145.65
	672	18	37.31	10.46	.34	.60	83.14	672	24	27.97	24.41	.75	1.05	71.13	672	9	48.00	8.00	—	.89	130.95
	672	14	48.00	16.35	.02	1.17	109.21	672	20	33.59	28.11	.23	1.42	51.42	672	9	74.66	4.45	.05	.50	184.00
	672	21	31.97	11.98	.64	.60	97.67	672	12	55.97	5.93	.31	.52	136.10	672	13	51.65	9.50	.50	.77	108.40
	360	7	51.42	8.69	.08	1.25	57.11	360	10	36.00	6.86	.12	.70	44.00	672	13	55.97	9.95	.33	.86	94.62
	312	8	38.90	5.74	.82	.82	28.82	312	15	20.74	3.78	.85	.31	21.90	672	12	56.00	46.45	—	3.87	158.60
	672	10	67.17	4.18	.25	.44	97.40	672	11	61.04	8.88	.58	.86	56.09	672	11	61.08	13.75	.10	1.26	141.70
	672	25	26.83	26.24	1.13	1.09	81.91	672	14	47.97	7.33	.43	.55	71.69	672	27	24.74	31.50	4.05	1.32	145.65
	456	6	76.00	2.02	—	.34	24.50	384	12	31.94	6.72	.68	.62	27.60	672	9	48.00	8.00	—	.89	130.95
1961	672	14	47.96	13.03	.62	.98	73.43	648	16	40.47	10.23	.45	.67	133.38	432	9	74.66	4.45	.05	.50	184.00
	672	25	26.86	11.56	.47	.48	77.71	576	12	47.97	8.18	.32	.71	46.17	672	13	51.65	9.50	.50	.77	108.40
	672	12	55.99	10.60	.15	.90	50.26	672	13	51.68	10.14	.10	.79	22.55	672	12	55.97	9.95	.33	.86	94.62
	672	27	24.80	61.52	2.33	2.36	93.25	672	12	55.99	6.77	.13	.57	65.54	672	13	51.68	11.83	.18	.92	88.25
	672	25	26.85	29.45	.76	1.21	63.79	672	14	47.97	10.91	.47	.81	24.32	672	6	111.99	18.72	.05	3.13	83.53
	672	16	41.97	10.86	.44	.71	54.83	672	7	95.97	3.32	.22	.51	17.28	672	15	44.76	9.42	.53	.66	113.03
	672	11	61.08	3.30	.16	.31	86.98	672	6	112.00	2.29	.03	.39	10.25	672	11	61.09	11.93	.02	1.09	205.20
	672	8	83.99	4.06	.05	.51	96.97	672	9	74.66	7.17	.05	.80	15.96	672	11	61.08	14.24	.10	1.30	184.85
	672	4	168.00	2.33	—	.58	122.42	672	12	55.98	12.10	.26	1.03	25.81	672	10	38.40	13.93	—	1.39	119.47
	384	3	128.00	1.53	—	.51	63.42	384	5	76.68	6.05	.60	1.33	13.83	384	10	38.40	13.93	—	1.39	119.47

Active Availability

Active availability is the percentage of time that either computer was available for performing air defense. In general, the higher the active availability, the better the maintenance.

$$\text{Active Availability} = \frac{\text{Total Time} - \text{LAD}}{\text{Total Time}} \times 100$$

Table VII

Active Availability Percentage*

Time Period	WAADS	BAADS	SYADS	NYADS	SSMDS
1	89				
2	88	97	91	95	
3	81	98	90	90	81
4	96	96	92	96	97

*99 omitted in each case

Standby Unavailability

Standby unavailability due to unscheduled maintenance is the ratio of unscheduled maintenance time to total time. In general, the lower the unscheduled maintenance time, the better the maintenance.

$$\text{Standby Unavailability} = \frac{\text{Unscheduled Maintenance}}{\text{Total Time}} \times 100$$

Table VIII
Standby Unavailability Percentage

Time Period	WAADS	BAADS	SYADS	NYADS	SSMDS
1	3.18				
2	4.52	2.00	1.94	4.08	
3	3.65	1.67	1.82	1.38	3.27
4	2.72	1.10	2.43	1.15	1.96

Mean Time to Failure

Mean time to failure (MTF) is the average failure rate for the system. In general, the higher the mean time to failure, the better the maintenance.

$$MTF = \frac{\text{Total Time} - \text{LAD}}{\text{Number of Failures}}$$

Table IX
Mean Time to Failure (Hours)

Time Period	WAADS	BAADS	SYADS	NYADS	SSMADS
1	21.61				
2	31.61	60.27	38.04	27.81	
3	27.65	95.98	39.24	40.76	42.29
4	37.40	65.21	47.96	65.21	55.89

Mean Time to Restore

Mean time to restore (MTR) following a failure is computed in Table X. In general, the lower the mean time to restore, the better the maintenance.

$$\text{MTR} = \frac{\text{Unscheduled Maintenance} + \text{LAD}}{\text{Number of Failures}}$$

Table X
Mean Time to Restore (Hours)

Time Period	WAADS	BAADS	SYADS	NYADS	SSMADS
1	.71				
2	1.47	1.23	.77	1.15	
3	1.06	1.62	.75	.61	1.47
4	1.03	.74	1.20	.78	1.11

Hours of Maintenance per 100 Hours of Useful Computer Time

This parameter is a measure of maintenance input to computer work output. In general, the lower the maintenance time input ratio, the better the maintenance. It is calculated as follows:

$$\text{Maintenance Effectiveness} = \frac{\underbrace{\frac{\text{Scheduled Maintenance}}{\text{Total Time} - \text{LAD}}}_{\text{Active Running Time}} + \underbrace{\frac{\text{Unscheduled Maintenance}}{\text{Mode A Time} + \text{Mode B Time}}}_{\text{Standby Running Time}}}{1} \times 100$$

Table XI
Hours of Maintenance per 100 Hours of Useful Computer Time

Time Period	WAADS	BAADS	SYADS	NYADS	SSMADS
1	23.63				
2	24.25	19.63	20.92	22.04	
3	23.17	19.00	21.46	20.92	21.38
4	23.04	18.88	22.34	20.33	20.46

APPENDIX D

AN/FSQ-7 SYSTEMS MEN

Men are selected from among the "units" technicians to receive advanced training in computer system maintenance. This additional training covers all areas of computer maintenance, and on completion of training the men become "systems" technicians. The systems technicians coordinate and handle common problems that arise within the three "units" maintenance areas; i. e. , input-output, display, and central computer.

At the beginning of Project Headstart, the only technicians at WAADS were those trained in one "unit." In February 1961, ten Air Force WAADS technicians were selected for systems training on the basis of their performance, training and on-the-job results, and Air Force rank. The selection chose the men equally from the different shifts and the different maintenance areas, as shown in the Table XII.

Table XII
Technicians Selected for Systems Training

Shift						
	ABC	DEF	GHJ	Quality Control		
No. Selected	3	3	3	1		
Maintenance Areas						
	I/O	DD	CC	GMS	QC	
No. Selected	2	2	3	2	1	
Air Force Rank						
	A/2	A/1	S/S	T/S	M/S	SM/S
Total WAADS	3	9	20	13	4	2
No. Selected	0	1	2	4	1	2

Data were collected on the training grades for the Air Force systems men and a sample group of IBM systems men. However, it was not possible to make a meaningful comparison between the two groups because the examinations were different. Table XIII summarizes the statistics for the systems course for each group.

Table XIII
Examination Average for Systems Course

	Exam Mean	Standard Deviation	Number
IBM	80.85	6.42	58
AF	82.53	9.71	10

A comparison was made between the IBM AN/FSQ-7 technicians and the Air Force WAADS technicians in terms of ability levels and previous achievement in the units training course. In Table XIV three groups are compared: a sample of IBM technicians, the WAADS group excluding the men selected for systems training, and the WAADS men selected for systems training.

Table XIV
Comparison of Ability and Performance in Units Course

				Significance of Difference AF Systems vs	
	IBM	WAADS	AF Systems	IBM	WAADS
Electronic Knowledge (FEAT I)	40.2	32.2	37.9	NS	>.02
Reasoning Ability (FEAT II)	44.4	37.2	38.9	>.001	NS
Intelligence (OTIS)	121.7	109.7	112.7	>.001	NS
Exam Grade	79.3	66.5	82.1	NS	>.01

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